HULL & NOURSE

An Investigation of the Motor Situation at the University of Illinois

Electrical Engineering

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AN INVESTIGATION OF THE MOTOR SITUATION AT THE UNIVERSITY OF ILLINOIS

BY

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THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1912

UNIVERSITY OF ILLINOIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

FREDERICK DAVIS HULL AND FRED MELVIN NOURSE

ENTITLED AN INVESTIGATION OF THE MOTOR SITUATION

AT THE UNIVERSITY OF ILLINOIS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

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HEAD OF DEPARTMENT OF ELECTRICAL ENGINEERING.

The three phase 2300 volt system has a 250 K.W.,3 conductor #4 B & S feeder running to a distribution point near the Law building. At this point the power is changed from three phase to two phase, 2300 volts to 440 volts through two 125 K.W. Scott transformers, and fed to the adjacent buildings. This system also has a 250 K.W.,3 conductor #4 B & S feeder running to Lincoln Hall and the Woman's building, where it feeds 30 K.W. transformers for lights and motors. This will be extended later to include the farm buildings and all new buildings south of Green street.

In the Road laboratory are two Scott 2 phase, 440 volt to 3 phase, 2300 volt transformers. By means of these the two systems can help each other when necessary, or they are just floated across the two systems.

The load on the power plant consists of lights and motors. The greater part of the motor load is on from 8 a.m. to 5 p.m. although some of the motors such as ventilating fans are on practically all the time.

The entire rated motor load is about 500 H.P. and the maximum lighting load about 150 K.W. In times of dark afternoons the heavy lighting load will come at the same time as the motor peak load, and this causes an additional peak load on the power plant. At such times as this several of the buildings have to be cut off so the generators can carry the load for buildings where light and power are most needed. From the present date this last condition will not be necessary on account of the auxiliary connection with the Illinois Traction System, which can be connected to the three phase

2300 volt system at the power plant.

In a great majority of cases the motors used are 2 phase 440 volts and of the squirrel cage type. Many of these have starting compensators. In general these motors have to start comparitively large loads or loads that have a good deal of static friction and inertia. A squirrel cage motor to have a fair speed regulation has an inherently poor starting torque and large starting current. Hence to start the load a larger motor than necessary for running conditions is required. Drawing comparitively large starting currents over a system of this size lowers the voltage and causes poor regulation. After the motor is up to speed it will take a large wattless current in comparison to its energy current, because it is not loaded up to its rated capacity. The effect of this is a low power factor at both the motor and power plant.

The Object of the Investigation.

The object of this investigation is to study the existing conditions and make such permissible recommendations as would help to improve the voltage regulation and raise the power factor.

Messers. Fisk and Turner of the Electrical Engineering department tested all the motors above one H.P. during the summer of 1911. Each motor was tested for K.W. input and starting currents. Wherever possible the compensators were adjusted to give nearly normal starting current. The reports of their test embody such recommendations as changes in starting and running fuses, changes in location of the compensator, fuse blocks and fuse cabinets. A tabulated copy of part of

the data they obtained is included in this thesis.

In making the recent tests, the data secured by Messers. Fisk and Turner was followed. It being the aim to choose the worst cases and to make a more complete test. Some new motors that have been installed recently were also tested. The data sheets for these new motors are marked "SPECIAL".

The purchasing and installing of motors in the various university buildings has in most cases been done in a haphazard way, and the result is a lot of poor installations. In almost all cases where motors are to be used to drive ventilating and heating fans, coal conveyors, heavy rotating machinery, or long line shafts, a large starting torque is required and not much power needed after starting. Since the squirrel cage motor gives poor starting conditions, a motor with a wound rotor resistance should be used for this class of work. The General Electric Company, Westinghouse Company, and the Wagner Company all make good motors of this type. The conditions under which each motor is to operate should be studied, and recommendations for the purchase made accordingly. Whenever it is advisable, any motor not now in use, should be used for new installations. The system could be bettered somewhat by taking motors that are now in use but not suited to conditions, and using them for new installations that will permit their use, and replacing the old motor with one designed for that particular class of work.

Under the present arrangement, in which each department owns the motors they use, transfers can not easily be made that would help conditions, except that in some cases motors

can be changed around in one department. We would recommend that a competent electrical engineer be appointed, and an engineering and motor department be created. The engineer in charge should have the proper authority to buy and sell motors to and from such departments as he saw fit, with the idea of improving the general lighting and power conditions. He should also have charge of the installing of all wiring, compensators, fuses, fuse boxes, distributing boards, transformers, cables, and so forth. A few hundred dollars spent in the right direction would do a great deal towards improving the lighting and power service.

Recommendations for Future Installations, Regarding Types of Motors, Fuses and Starters.

In the past very little attention seems to have been given to the matter of fuses, fuse boxes, compensators, and the general operation of the motors. Starting at the distributing point of that building, each motor should have its own separate leads, and whenever the size of wire is changed it should be protected by fuses. Compensators should be located so the operator can see the motor. Wherever the compensator is located there should be provided an iron fuse box and proper running fuses. A very good equipment in this respect is used with the 7 1/2 H.P. motor located in the center of the basement of Lincoln Hall. We would advise that in all new installations similar equipment be used.

Due to the limit in time and the large number of motors in use, this investigation could not be carried to any great ex-

tent, nor any very definite recommendations made. What has been set forth will give a general idea of the present conditions and also advise on future installations, which if followed will raise the power factor and output of the power plant, and besides improve the voltage regulation.

Since the purchase of power from the Illinois Traction System is now possible, it would seem that the improvements to be gained by following the recommendations in this thesis, would be very valuable from a financial standpoint. The power used is all metered and any unnecessary use of power would be an additional cost to the power plant expenses.

Motor Test- SPECIAL.

Location- New boiler room.

Nature of Service- Coal conveyor.

---TEST---

Voltage-450 Speed-850 H.P.-5 Compensator--Yes.

	Input	P.F.	Currents
No Load	.8 K.W.		Starting--
Loaded	2.4 K.W.	.59	Running--- 4.5 amps. max.

Loaded reading taken with hopper full.

Fuses--Starting, None
Running, 15 amps.

Description of Motor.

Westinghouse type CCL 5 H.P.-450 volt-6.05 amps./phase-

2 phase-60 cycle-850 R.P.M.-Serial #825832 Style #126673

Remarks.

Motor would not start on the first point.

Recommendations.

This equipment should be provided with a clutch, or have a motor with a rotor resistance.

Motor Test #17

Location--Ceramics laboratory.

Nature of Service-- Line shafting.

---TEST---

Voltage-460 Speed-1120 H.P.-10 Compensator--Yes.

	Input	P.F.	Currents
No Load	1 K.W.		Starting-18,5,and 5 amps.
Loaded	3 K.W.		Running-- 5 amps.

Running current goes to 7 amps. when grinder is started.

Fuses--Starting, 30 amps.
Running, 15 amps.

Description of Motor.

Westinghouse Type CCL, 2 phase induction motor-10 H.P.-400 volts-60 cycles-1120 R.P.M.-13.2 amps./terminal-Serial #373749

Remarks.

Recommendations.

A smaller motor of the same type would be better(5 H.P.).

Motor Test #18

Location--Physics fan room.

Nature of Service--Ventilating fan.

---TEST---

Voltage-460 Speed-1200 H.P.-15 Compensator--Auto-starter.

	Input	P.F.	Currents
No Load			Starting--55 and 14 amps.
Loaded	5.6 K.W.	.51	Running---12 amps.

Fuses--Starting, 30 amps.
Running, 15 amps.

Description of Motor.

Fort Wayne Type M-6-15-1200 Form C-2 phase-60 cycle

17 amps./terminal-440 volts-Serial #179627

Remarks.

Has Cutler-Hammer A.C. auto-starter, 18 amps.

Recommendations.

A 10 H.P. motor is large enough for this work, and would give better starting conditions if it had rotor resistance to start it.

Motor Test #19

Location--Physics fan room.

Nature of Service--Ventilating fan.

---TEST---

Voltage-460 Speed-1200 H.P.-10 Compensator--Auto-starter.

	Input	P.F.	Currents
No Load			Starting--31 and 7 amps.
Loaded	2.4 K.W.	.52	Running---7 amps.

Fuses--Starting, 25 amps.
Running, 15 amps.

Description of Motor.

Fort Wayne Type M-6-10-1200 Form C-2 phase-60 cycle-440 volt-1200 R.P.M.-12 amps./terminal--Serial#178739

Remarks.

Has Cutler-Hammer A.C. auto-starter, 12 amps.

Recommendations.

A 5 H.P. motor is large enough for this fan, and would give better starting conditions if it had rotor resistance to start it.

Motor Test #22

Location--Physics building; mechanicians shop.

Nature of Service--Line shaft for machine tools.

---TEST---

Voltage-450 Speed-1200 H.P.-5 Compensator--Yes.

	Input	P.F.	Currents
No Load			Starting- 29 amps.
Loaded	1.6 K.W.	.89	Running-- 2 amps.

Fuses--Starting, None
Running, 10 amps.

Description of Motor.

General Electric Type 10, Class 8-5-1200 Form K-60 cycles

5 H.P.-440 volt--Serial #78115

Remarks.

The motor apparently gets nearly full potential on the first point of the compensator.

Recommendations.

Compensator should be reconnected to give better starting conditions.

Motor Test #36

Location--Chemistry fan room.

Nature of Service--Ventilating fan.

---TEST---

Voltage-460 Speed-900 H.P.-20 Compensator--Rotor resist.

	Input	P.F.	Currents
No Load			Starting---25 amps.
Loaded	10 K.W.	.68	Running----13 amps.

Fuses--Starting, 30 amps.
Running, "

Description of Motor.

General Electric induction motor Type 1Q Form L-Class 8-20-

900 R.P.M.-22 amps./terminal-2 phase-Serial #68572

Remarks.

Recommendations.

A smaller motor of the same type could be used here(10 H.P)

Motor Test #41-A

Location--Pump house east of the Electrical laboratory.

Nature of Service--Belted water pump.

---TEST---

Voltage-450 Speed-850 H.P.-5 Compensator--Yes.

	Input	P.F.	Currents
No Load			Starting
Loaded	4.8 K.W.	.96	Running---5.5 amps.

Fuses--Starting, None
Running, 15 amps.

Description of Motor.

Westinghouse Type CCL induction motor,-5 H.P.-440 volts 5.05 amps./terminal-2 phase-850 R.P.M.

Remarks.

Wattmeter needle vibrated between 0 and 8000 watts while running.

Recommendations.

Motor is working at 50% overload, and it would be better to have a 7.5 H.P. motor with a rotor resistance.

Motor Test #48

Location--Wood shop basement.

Nature of Service--Line shaft for woodworking machines.

---TEST---

Voltage-435 Speed- H.P.- Compensator--Yes.

	Input	P.F.	Currents
No Load	3.2 K.W.	.53	Starting-12.5-30.5-and29 amps.
Loaded	9.6 K.W.	.735	Running-7 amps. and 15 amps.

Fuses--Starting, None
Running, 30 amps.

Description of Motor.

Westinghouse squirrel cage-400 volts. No other data found as name plate was not marked.

Remarks.

The running current goes to 18 amps. when all of the machines are started one after the other. Motor does not start on the first point.

Recommendations.

A smaller motor could be used here(about 15 H.P.).

Motor Test #47

Location--Foundry basement.

Nature of Service--Shafting and cupola blower.

---TEST---

Voltage-430 Speed-1120 H.P.-10 Compensator--Yes.

	Input	P.F.	Currents
No Load			Starting--23 amps.
Loaded	9.6 K.W.	.89	Running---12.5 amps.

Fuses--Starting, None
Running, refilled 50 amps.

Description of Motor.

Westinghouse Type C induction motor-10 H.P.-400 volts-2 phase-13.7 amps./terminal.

Remarks.

Motor does not start on the first point. Fuses carry both starting and running currents.

Recommendations.

This installation should have enclosed fuses and better fuse cabinet. Smaller running fuses should be used and compensator reconnected.

Motor Test #49

Location--Natural History fan room.

Nature of Service--Ventilating fan.

---TEST---

Voltage-435 Speed- H.P.-30 Compensator--Yes.

	Input	P.F.	Currents
No Load			Starting-- 50 amps.
Loaded	16 K.W.	.475	Running--- 38 amps.

Fuses--Starting, fuses on main board.
Running, 50 amps.

Description of Motor.

Westinghouse Type CCL-30 H.P.-400 volts-37 amps./terminal 2 phase-60 cycle-850 R.P.M.-Serial #636378. Westinghouse compensator.

Remarks.

Motor is rather noisy.

Recommendations.

Any change that might be made here would be to install a motor with a rotor resistance, and it might also be well to have a smaller motor since this one is not carrying its full rated output.

Motor Test #52

Location--Pump house north of Electrical laboratory.

Nature of Service--Belted water pump.

---TEST---

Voltage-440 Speed-1120 H.P.-15 Compensator--Yes.

	Input	P.F.	Currents
No Load			Starting-15-35-and 15 amps.
Loaded	5.6 K.W.	.64	Running--10 amps.

Fuses--Starting,
Running, 25 amps.

Description of Motor.

Westinghouse Type C induction motor-15 H.P.-400 volts

19 amps./terminal-1200 R.P.M.

Remarks.

Motor does not start on yhe first point.

Recommendations.

A smaller motor could be used here.(10 H.P.,rotor resist.)

Motor Test #53

Location--Old boiler room.

Nature of Service--Mechanical stokers and coal conveyors.

---TEST---

Voltage-460 Speed-850 H.P.-20 Compensator--Yes.

	Input	P.F.	Currents
Stokers	2.5 K.W.	.226	12 amperes
Start convey			30 "
Convey.& stok.	13. K.W.	.785	18 "
Ash dump & "	5 K.W.	.410	13 "

Starting-10 and 10 amps.

Fuses--Starting, 30 amps.
Running, "

Description of Motor.

Westinghouse Type CCL induction motor-20 H.P.-25.5 amps. per terminal-2 phase-60 cycle-400 volts-850 R.P.M.

Serial #479381

Remarks.

Recommendations.

A 5 H.P. motor should be installed to run the ash dumper and stokers. Use the present motor for the conveyor only.

Motor Test #57

Location--Machine shop.

Nature of Service--Line shaft for machine tools.

---TEST---

Voltage-440 Speed- H.P.-25 Compensator--Yes.

	Input	P.F.	Currents
No Load	1.2 K.W.		Starting-42 and 23 amps.
Loaded	4.0 K.W.	.45	Running--10 amps. shafts alone.

Fuses--Starting, 75 amps.
Running, "

Description of motor.

440 volts-17 amps./terminal-2 phase.

Remarks.

Recommendations.

This motor should be removed and replaced by two 7.5 H.P. motors, one for each main line shaft, and have each shaft split into two sections with a clutch between.

Motor Test-SPECIAL.

Location--Lincoln Hall.

Nature of Service--Ventilating fan.

---TEST---

Voltage-216 Speed-1200 H.P.-5 Compensator--None.

	Input	P.F.	Currents
No Load			Starting--75 and 25 amps.
Loaded	3.5 K.W.	.78	Running---12 amps.

Wattmeter A- 2.5 K.W.
" B- 1.0 K.W.

Fuses--Starting, 15 amps.
Running, "

Description of Motor.

Sprague Electric induction motor #430122--Type R-6-5A-1200 R.P.M. Form FT-60 cycles-5 H.P.-220 volts-3 phase-13.2 amp.

Remarks.

Motor has trouble in starting without the compensator and sometimes causes the belt to fly off.

Recommendations.

Motor should have a compensator, or install a motor with a resistance in the rotor.

Motor Test-SPECIAL.

Location--Lincoln Hall.

Nature of Service--Passenger elevator.

---TEST---

Going Up.				Going Down				P.F.
Phase A to B.				Phase A to B				Down .50
	I	E	K.W.		I	E	K.W.	
Start	80	224		Start	80	226		Up .18
Run	42	224	6.0	Run	46	226	S.S	
Phase A to C				Phase A to C				
Start	75	224		Start	80	226		
Run	41	224	-3.0	Run	46	226	0.0	

Fuses--Starting,
Running,

Description of Motor.

Warner Elevator Mfg. Co. Type 1110 #2049 3 phase-60 cycle 220 volt-50 amps.-15 H.P.- 8 poles-850 R.P.M.- Automatic controller-wound rotor with slip rings and an external resistance.

Remarks.

Motor has wound rotor with external resistance, operated by an automatic elevator starter.

Motor Test #1

Location--Wood shop lathe room.

Nature of Service--Line shaft for wood lathes.

---TEST---

Voltage-425 Speed-1140 H.P.-7.5 Compensator--Yes.

	Input	P.F.	Currents
No Load			
Phase-A	1.2 K.W.	.47	Starting line shaft--29 amps.
" B	1.2 "		
			Running line shaft-- 7 amps.
Loaded			
Phase-A	2.4 K.W.	.81	
" B	2.4 "		

Fuses--Starting, 25 amps.
Running, 15 "

Description of Motor.

Westinghouse Type CCL induction motor-7.5 H.P.-400 volts 10 amps-2 phase-60 cycle-1120 R.P.M.

Recommendations.

Compensator should be removed from tool room to position near the motor so operator can observe starting of motor.

A clutch should be provided so the motor will not have to start all the line shafting at once.

A 10 H.P. motor would probably be better for this place, since they have trouble with the motor slowing down when shop is running full force.

Unless clutch is used a motor with a resistance in the rotor would give much better satisfaction.

Motor Test-SPECIAL.

Location--Lincoln Hall.

Nature of Service--Ventilating fan.

---TEST---

Voltage-225 Speed-1180 H.P.-7.5 Compensator--Yes.

	Input	P.F.	Currents
No Load			
Loaded	7.6 K.W.	.85	Starting--23 and 60 amps. Running---23 amps.
Wattmeter-A	6.6 K.W.		
" B	1.0 K.W.		

Fuses--Starting, on main board.
Running, 25 amps.

Description of Motor.

Sprague Electric induction motor #406683 Type R-6-7.5A-1200-Form FT-60 cycles-220 volts-3 phase-19 amps.

Remarks.

Motor does not get enough voltage on the first point and too much on the second. It jerks badly in changing from start to running position.

Recommendations.

The load requires a larger motor (10 H.P.), and compensator should be readjusted.

Motor Test-SPECIAL.

Location--Lincoln Hall.

Nature of Service--Ventilating fan.

---TEST---

Voltage-230 Speed-1200 H.P.-5 Compensator--None.

	Input	P.F.	Currents
No Load			Starting--52 and 43 amps.
Loaded	5.5 K.W.	.73	Running---10 amps.

Fuses--Starting, 15 amps.
Running, 15 "

Description of Motor.

Sprague Electric #430542--Type R-6-5A-1200 Form FT-3 phase 60 cycle-5 H.P.-220 volts-13.2 amps./terminal.

Remarks.

The motor starts badly on account of the absence of a compensator.

Recommendations.

A larger motor is required here(7.5 H.P.), with a compensator or a motor with a rotor resistance.

	Building	Location	Service	H.P.	K.W.	I_r	I_s	I_l	R.P.M.
#1	Wood shop	Lathe room	Shafting	7.5	2.5	10	30	30	1120
#2	" "	Basement	"	5.0	2.5	6	30	30	1120
#3	" "	Tool room	Grinder	1.0	---	1.3	3	3	----
#4	" "	Cabinet "	Blower	5.0	2.75	6	30	18	1200
#5	Machine "	Forge room	"	7.5	8.25	9.7	45	15	840
#6	" "	" "	"	5.0	2.5	7	86	13	1200
#7	" "	" "	"	10.0	9.0	13	16	16	850
#8	" "	" "	"	7.5	5.7	8.9	17	17	1700
#9	M.E. Lab.	Crane	Traction	10.0	---	---	---	10	----
#10	"	"	Hoist	5.0	3.2	---	---	15	----
#11	"	"	Trolley	7.5	1.0	---	---	8	900
#12	"	Lab. D.C.	Oil test	1.0	---	4.2	---	---	1275
#13	"	" "	Blower	10.0	---	---	---	---	1430
#14	"	Not in use	--------	7.5	---	10.7	---	---	1200
#15	Road Lab.	Road Lab.	Shafting	2.0	---	2.25	---	---	1800
#16	" "	" "	Rattler	10	---	12	20	20	1200
#17	Ceramics	Basement	Shafting	10	---	13.2	12	12	1120
#18	Physics	Fan room	Fan	15	9.2	17	48	48	1200
#19	"	" "	"	10	5.0	12	30	30	1200
#20	"	Shop	Mot.Gen.	15	1.7	17	60	60	1200
#21	"	Fan room	Fan	2.0	---	2.5	---	---	1200
#22	"	Shop	Shafting	5.0	2.0	6.0	29	18	1200
#23	"	Students "	"	2.0	---	2.25	---	---	1800
#24	Hydraulics	Test Lab.	"	10	1.25	12	29	29	1200
#25	"	" "	Tester	1.0	---	1.6	7	7	1700
#26	"	Shop	Shafting	5.0	---	6.5	30	30	900
#27	"	Laboratory	Pumps	10	---	12	---	---	1200
#28	"	Pit	Tester	15	---	17	75	49	1200
#29	Library	Basement	Fan	20	11.5	---	40	40	1200
#30	Agricult.	Churn room	Shafting	5.0	---	6.5	?	20	1200
#31	"	Room 502	Grinder	5.0	---	5.8	33	33	1200
#32	"	" 137	"	5.0	---	6.2	29	29	1700
#33	"	Dairy dept	Refrig.	15	8.0	19	31	31	690
#34	"	Room 657	Shafting	3.0	---	4.0	20	20	1700
#35	"	" 315	"	5.0	---	6.5	21	21	1120
#36	Chemistry	Basement	Fan	20	10	22	25	25	900
#37	"	"	Gen.	3.0	.8	3.8	22	22	1800
#38	"	"	Shafting	5.0	1.2	8.0	12	12	840
#39	"	"	Fan	3.0	2.0	3.6	17	17	1200
#40	Agronomy	Agronomy	Shafting	15	12	19	20	20	1120
#41	E.E. Lab.	Pump house	Pump	7.5	5.0	10	10	10	1120
#42	Water sta.	----------	"	7.5	3.6	10	10	10	1120
#43	Dairy barn	Dairy barn	Grinder	15	5.2	13.2	55	40	1120
#44	" "	" "	Sheller	2.0	1.0	4.7	17	17	1120
#45	Farm mech.	Farm mech.	Gen.	15	2.0	19	52	35	1120
#46	Cattle blg	Cattle blg	Grinder	15	2.8	19	35	35	1120
#47	Wood shop	Basement	Shafting	10	1.4	13.7	45	10	1120
#48	"	"	"	20	8.0	---	11	11	1120
#49	Nat. Hist.	"	Fan	30	8.0	37	50	50	840
#50	"	"	Gen.	15	2.0	16.5	20	20	1800
#51	"	Attic	Fan	5.0	2.1	5.0	11.5	11	840
#52	Pump hse.	Pump hse.	Pump	15	5.6	19	90	15	1200
#53	Power hse.	E.E. Lab.	Shafting	20	2.5	25.5	28	28	850
#54	E.E. shop	Basement	"	7.5	1.2	10	24	9	1120

	Building	Location	Service	H.P.	K.W.	I_r	I_s	I_l	R.P.M.
#55	Physics	Fan room	Vac.pump	2.0	----	2.8	-----	---	-----
#56	Library	Basement	Elevator	---	(550 volts D.C.).				
#57	M.E. shop	Shop	Tin shop	25	----	---	-----	---	-----

Nomenclature.

I_r= Rated current.

I_s= Starting current as found.

I_l= Starting current as left.